JC10 Rec'd PCT/PTO 04 JAN 2002

Practitioner's Docket No. 776-010802-US(PAR)

CHAPTER II 10/030366

Preliminary Classification:

Proposed Class:

Subclass:

NOTE: "All applicants are requested to include a preliminary classification on newly filed patent applications. The preliminary classification, preferably class and subclass designations, should be identified in the upper right-hand corner of the letter of transmittal accompanying the application papers, for example 'Proposed Class 2, subclass 129.'" M.P.E.P., § 601, 7th ed.

TRANSMITTAL LETTER
TO THE UNITED STATES ELECTED OFFICE (EO/US)
(ENTRY INTO U.S. NATIONAL PHASE UNDER CHAPTER II)

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/CA00/00808	7 July 2000	7 July 1999

TITLE OF INVENTION

Method And System For Producing A Higher Quality Electromyographic Signal From An Electrode Array

APPLICANT(S)

Christer SINDERBY, Jennifer BECK, Lars LINDSTROM

Box PCT
Assistant Commissioner for Patents
Washington D.C. 20231
ATTENTION: EO/US

CERTIFICATION UNDER 37 C.F.R. §§ 1.8(a) and 1.10*

(When using Express Mail, the Express Mail label number is mandatory; Express Mail certification is optional.)

I hereby certify that, on the date shown below, this correspondence is being:

MAILING

☒ deposited with the United States Postal Service in an envelope addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231

37 C.F.R. § 1.8(a)

☐ with sufficient postage as first class mail.

37 C.F.R. § 1.10 *

☒ as "Express Mail Post Office to Addressee"

Mailing Label No. EL627511083US **(mandatory)**

TRANSMISSION

☐ facsimile transmitted to the Patent and Trademark Office, (703) ______-______.

Date: December 4, 2001

Signature

Emily Hajus

(type or print name of person certifying)

* *Only the date of filing (§ 1.6) will be the date used in a patent term adjustment calculation, although the date on any certificate of mailing or transmission under § 1.8 continues to be taken into account in determining timeliness. See § 1.703(f). Consider "Express Mail Post Office to Addressee" (§ 1.10) or facsimile transmission (§ 1.6(d)) for the reply to be accorded the earliest possible filing date for patent term adjustment calculations.*

NOTE: To avoid abandonment of the application, the applicant shall furnish to the USPTO, not later than 20 months from the priority date: (1) a copy of the international application, unless it has been previously communicated by the International Bureau or unless it was originally filed in the USPTO; and (2) the basic national fee (see 37 C.F.R. § 1.492(a)). The 30-month time limit may not be extended. 37 C.F.R. § 1.495.

WARNING: *Where the items are those which can be submitted to complete the entry of the international application into the national phase are subsequent to 30 months from the priority date the application is still considered to be in the international state and if mailing procedures are utilized to obtain a date the express mail procedure of 37 C.F.R. § 1.10 must be used (since international application papers are not covered by an ordinary certificate of mailing—See 37 C.F.R. § 1.8.*

NOTE: Documents and fees must be clearly identified as a submission to enter the national state under 35 U.S.C. § 371 otherwise the submission will be considered as being made under 35 U.S.C. § 111. 37 C.F.R. § 1.494(f).

I. Applicant herewith submits to the United States Elected Office (EO/US) the following items under 35 U.S.C. § 371:

a. ☒ This express request to immediately begin national examination procedures (35 U.S.C. § 371(f)).

b. ☒ The U.S. National Fee (35 U.S.C. § 371(c)(1)) and other fees (37 C.F.R. § 1.492) as indicated below:

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2. Fees

CLAIMS FEE	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
☐*	TOTAL CLAIMS 28	28 −20=	8	× $18.00=	$ 144.00
	INDEPENDENT CLAIMS 2	2 −3=	0	× $84.00 =	0
	MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+$ 280.00 =	
BASIC FEE**	☐ U.S. PTO WAS INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where an International preliminary examination fee as set forth in § 1.482 has been paid on the international application to the U.S. PTO: ☐ and the international preliminary examination report states that the criteria of novelty, inventive step (non-obviousness) and industrial activity, as defined in PCT Article 33(1) to (4) have been satisfied for all the claims presented in the application entering the national stage (37 C.F.R. § 1.492(a)(4)) .... $100.00 ☐ and the above requirements are not met (37 C.F.R. § 1.492(a)(1)) ....$ 710.00 XX U.S. PTO WAS NOT INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where no international preliminary examination fee as set forth in § 1.482 has been paid to the U.S. PTO, and payment of an international search fee as set forth in § 1.445(a)(2) to the U.S. PTO: ☐ has been paid (37 C.F.R. § 1.492(a)(2)) ....$ 740.00 ☐ has not been paid (37 C.F.R. § 1.492(a)(3)) ..$1,040.00 XX where a search report on the international application has been prepared by the European Patent Office or the Japanese Patent Office (37 C.F.R. § 1.492(a)(5)) .... $ 890.00				890.00
	Total of above Calculations				= 1,034.00
SMALL ENTITY	Reduction by 1/2 for filing by small entity, if applicable. Assertion must be made. (note 37 C.F.R. § 1.27)				− 517.00
	Subtotal				
	Total National Fee				$517.00
	Fee for recording the enclosed assignment document $40.00 (37 C.F.R. § 1.21(h)). (See Item 13 below). See attached "ASSIGNMENT COVER SHEET".				
TOTAL	Total Fees enclosed				$ 517.00

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*See attached Preliminary Amendment Reducing the Number of Claims.

☒ Attached is a ☒ check ☐ money order in the amount of $ 517.00

☐ Authorization is hereby made to charge the amount of $

☒ to Deposit Account No. 16-1350

☐ to Credit card as shown on the attached credit card information authorization form PTO-2038.

WARNING: *Credit card information should **not** be included on this form as it may become public.*

☒ Charge any additional fees required by this paper or credit any overpayment in the manner authorized above.

A duplicate of this paper is attached.

****WARNING:*** *"To avoid abandonment of the application the applicant shall furnish to the United States Patent and Trademark Office not later than the expiration of 30 months from the priority date: * * * (2) the basic national fee (see § 1.492(a)). The 30-month time limit may not be extended." 37 C.F.R. § 1.495(b).*

WARNING: *If the translation of the international application and/or the oath or declaration have not been submitted by the applicant within thirty (30) months from the priority date, such requirements may be met within a time period set by the Office. 37 C.F.R. § 1.495(b)(2). The payment of the surcharge set forth in § 1.492(e) is required as a condition for accepting the oath or declaration later than thirty (30) months after the priority date. The payment of the processing fee set forth in § 1.492(f) is required for acceptance of an English translation later than thirty (30) months after the priority date. Failure to comply with these requirements will result in abandonment of the application. The provisions of § 1.136 apply to the period which is set. Notice of Jan. 3, 1993, 1147 O.G. 29 to 40.*

☒ **Assertion of Small Entity Status**

☒ **Applicant hereby asserts status as a small entity under 37 C.F.R. § 1.27.**

NOTE: 37 C.F.R. § 1.27(c) deals with the assertion of small entity status, whether by a written specific declaration thereof or by payment as a small entity of the basic filing fee or the fee for the entry into the national phase as states:

"(c) Assertion of small entity status. Any party (person, small business concern or nonprofit organization) should make a determination, pursuant to paragraph (f) of this section, of entitlement to be accorded small entity status based on the definitions set forth in paragraph (a) of this section, and must, in order to establish small entity status for the purpose of paying small entity fees, actually make an assertion of entitlement to small entity status, in the manner set forth in paragraphs (c)(1) or (c)(3) of this section, in the application or patent in which such small entity fees are to be paid.

(1) Assertion by writing. Small entity status may be established by a written assertion of entitlement to small entity status. A written assertion must:

(i) Be clearly identifiable;

(ii) Be signed (see paragraph (c)(2) of this section); and

(iii) Convey the concept of entitlement to small entity status, such as by stating that applicant is a small entity, or that small entity status is entitled to be asserted for the application or patent. While no specific words or wording are required to assert small entity status, the intent to assert small entity status must be clearly indicated in order to comply with the assertion requirement.

(2) Parties who can sign and file the written assertion. The written assertion can be signed by:

(i) One of the parties identified in §§ 1.33(b) (e.g., an attorney or agent registered with the Office), §§ 3.73(b) of this chapter notwithstanding, who can also file the written assertion;

(ii) At least one of the individuals identified as an inventor (even though a §§ 1.63 executed oath or declaration has not been submitted), notwithstanding §§ 1.33(b)(4), who can also file the written assertion pursuant to the exception under §§ 1.33(b) of this part; or

(iii) An assignee of an undivided part interest, notwithstanding §§ 1.33(b)(3) and 3.73(b) of this chapter, but the partial assignee cannot file the assertion without resort to a party identified under §§ 1.33(b) of this part.

(3) *Assertion by payment of the small entity basic filing or basic national fee. The payment, by any party, of the exact amount of one of the small entity basic filing fees set forth in §§ 1.16(a), (f), (g), (h), or (k), or one of the small entity basic national fees set forth in §§ 1.492(a)(1), (a)(2), (a)(3), (a)(4), or (a)(5), will be treated as a written assertion of entitlement to small entity status even if the type of basic filing or basic national fee is inadvertently selected in error.*

(i) If the Office accords small entity status based on payment of a small entity basic filing or basic national fee under paragraph (c)(3) of this section that is not applicable to that application, any balance of the small entity fee that is applicable to that application will be due along with the appropriate surcharge set forth in §§ 1.16(e), or §§ 1.16(l).

(ii) The payment of any small entity fee other than those set forth in paragraph (c)(3) of this section (whether in the exact fee amount or not) will not be treated as a written assertion of entitlement to small entity status and will not be sufficient to establish small entity status in an application or a patent."

3. ☒ A copy of the International application as filed (35 U.S.C. § 371(c)(2)):

NOTE: Section 1.495 (b) was amended to require that the basic national fee and a copy of the international application must be filed with the Office by 30 months from the priority date to avoid abandonment. "The International Bureau normally provides the copy of the international application to the Office in accordance with PCT Article 20. At the same time, the International Bureau notifies applicant of the communication to the Office. In accordance with PCT Rule 47.1, that notice shall be accepted by all designated offices as conclusive evidence that the communication has duly taken place. Thus, if the applicant desires to enter the national stage, the applicant normally need only check to be sure the notice from the International Bureau has been received and then pay the basic national fee by 30 months from the priority date." Notice of Jan. 7, 1993, 1147 O.G. 29 to 40, at 35-36. See item 14c below.

a. ☒ is transmitted herewith.

b. ☐ is not required, as the application was filed with the United States Receiving Office.

c. ☐ has been transmitted

i. ☐ by the International Bureau.

Date of mailing of the application (from form PCT/1B/308):

______________.

ii. ☐ by applicant on ______________. *(Date)*

4. ☒ A translation of the International application into the English language (35 U.S.C. § 371(c)(2)):

a. ☐ is transmitted herewith.

b. ☒ is not required as the application was filed in English.

c. ☐ was previously transmitted by applicant on __________. *(Date)*

d. ☐ will follow.

5. XX Amendments to the claims of the International application under PCT Article 19 (35 U.S.C. § 371(c)(3)):

NOTE: The Notice of January 7, 1993 points out that 37 C.F.R. § 1.495(a) was amended to clarify the existing and continuing practice that PCT Article 19 amendments must be submitted by 30 months from the priority date and this deadline may not be extended. The Notice further advises that: "The failure to do so will not result in loss of the subject matter of the PCT Article 19 amendments. Applicant may submit that subject matter in a preliminary amendment filed under section 1.121. In many cases, filing an amendment under section 1.121 is preferable since grammatical or idiomatic errors may be corrected." 1147 O.G. 29-40, at 36.

- a. ☐ are transmitted herewith.
- b. ☐ have been transmitted
  - i. ☐ by the International Bureau.
    Date of mailing of the amendment (from form PCT/1B/308):
    ______________.
  - ii. ☐ by applicant on ______________. *(Date)*
- c. XX have not been transmitted as
  - i. XXX applicant chose not to make amendments under PCT Article 19.
    Date of mailing of Search Report (from form PCT/ISA/210.):
    12/12/00 __________.
  - ii. ☐ the time limit for the submission of amendments has not yet expired. The amendments or a statement that amendments have not been made will be transmitted before the expiration of the time limit under PCT Rule 46.1.

6. X A translation of the amendments to the claims under PCT Article 19 (38 U.S.C. § 371(c)(3)):
- a. ☐ is transmitted herewith.
- b. ☐ is not required as the amendments were made in the English language.
- c. XX has not been transmitted for reasons indicated at point 5(c) above.

7. XX A copy of the international examination report (PCT/IPEA/409)
- X is transmitted herewith.
- ☐ is not required as the application was filed with the United States Receiving Office.

8. ☐ Annex(es) to the international preliminary examination report
- a. ☐ is/are transmitted herewith.
- b. ☐ is/are not required as the application was filed with the United States Receiving Office.

9. ☐ A translation of the annexes to the international preliminary examination report
- a. ☐ is transmitted herewith.
- b. ☐ is not required as the annexes are in the English language.

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10. [x] An oath or declaration of the inventor (35 U.S.C. § 371(c)(4)) complying with 35 U.S.C. § 115

a. [ ] was previously submitted by applicant on ________________. *(Date)*

b. [ ] is submitted herewith, and such oath or declaration

i. [ ] is attached to the application.

ii. [ ] identifies the application and any amendments under PCT Article 19 that were transmitted as stated in points 3(b) or 3(c) and 5(b); and states that they were reviewed by the inventor as required by 37 C.F.R. § 1.70.

c. [x] will follow.

II. Other document(s) or information included:

11. [x] An International Search Report (PCT/ISA/210) or Declaration under PCT Article 17(2)(a):

a. [x] is transmitted herewith.

b. [ ] has been transmitted by the International Bureau.

Date of mailing (from form PCT/IB/308): ________________.

c. [ ] is not required, as the application was searched by the United States International Searching Authority.

d. [ ] will be transmitted promptly upon request.

e. [ ] has been submitted by applicant on ________________. *(Date)*

12. [x] An Information Disclosure Statement under 37 C.F.R. §§ 1.97 and 1.98:

a. [ ] is transmitted herewith.

Also transmitted herewith is/are:

[ ] Form PTO-1449 (PTO/SB/08A and 08B).

[ ] Copies of citations listed.

b. [x] will be transmitted within THREE MONTHS of the date of submission of requirements under 35 U.S.C. § 371(c).

c. [ ] was previously submitted by applicant on ________________. *(Date)*

13. [ ] An assignment document is transmitted herewith for recording.

A separate [ ] "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or [ ] FORM PTO 1595 is also attached.

14. ☒ Additional documents:
   a. ☒ Copy of request (PCT/RO/101)
   b. ☒ International Publication No. WO 01/03579 A1
      i. ☒ Specification, claims and drawing
      ii. ☐ Front page only
   c. ☒ Preliminary amendment (37 C.F.R. § 1.121)
   d. ☒ Other

   PCT/RO/101; PCT/IPEA/401; PCT/IPEA/408; PCT/IPEA/416; PCT/IPEA/409

15. ☒ The above checked items are being transmitted
   a. ☒ before 30 months from any claimed priority date.
   b. ☐ after 30 months.

16. ☐ Certain requirements under 35 U.S.C. § 371 were previously submitted by the applicant on ____________, namely:

AUTHORIZATION TO CHARGE ADDITIONAL FEES

WARNING: *Accurately count claims, especially multiple dependant claims, to avoid unexpected high charges if extra claims are authorized.*

NOTE: *"A written request may be submitted in an application that is an authorization to treat any concurrent or future reply, requiring a petition for an extension of time under this paragraph for its timely submission, as incorporating a petition for extension of time for the appropriate length of time. An authorization to charge all required fees, fees under § 1.17, or all required extension of time fees will be treated as a constructive petition for an extension of time in any concurrent or future reply requiring a petition for an extension of time under this paragraph for its timely submission. Submission of the fee set forth in § 1.17(a) will also be treated as a constructive petition for an extension of time in any concurrent reply requiring a petition for an extension of time under this paragraph for its timely submission." 37 C.F.R. § 1.136(a)(3).*

NOTE: *"Amounts of twenty-five dollars or less will not be returned unless specifically requested within a reasonable time, nor will the payer be notified of such amounts; amounts over twenty-five dollars may be returned by check or, if requested, by credit to a deposit account." 37 C.F.R. § 1.26(a).*

☒ Please charge, in the manner authorized above, the following additional fees that may be required by this paper and during the entire pendency of this application:

   ☒ 37 C.F.R. § 1.492(a)(1), (2), (3), and (4) (filing fees)

WARNING: *Because failure to pay the national fee within 30 months without extension (37 C.F.R. § 1.495(b)(2)) results in abandonment of the application, it would be best to always check the above box.*

☒ 37 C.F.R. § 1.492(b), (c) and (d) (presentation of extra claims)

NOTE: Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid or these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 C.F.R. § 1.492(d)), it might be best not to authorize the PTO to charge additional claim fees, except possible when dealing with amendments after final action.

☒ 37 C.F.R. § 1.17 (application processing fees)

☒ 37 C.F.R. § 1.17(a)(1)–(5) (extension fees pursuant to § 1.136(a).

☐ 37 C.F.R. § 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. § 1.311(b))

NOTE: Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the issue fee will be automatically charged to the deposit account at the time of mailing the notice of allowance. 37 C.F.R. § 1.311(b).

NOTE: 37 C.F.R. § 1.28(b) requires "Notification of any change in loss of entitlement to small entity status must be filed in the application . . . prior to paying, or at the time of paying . . . issue fee." From the wording of 37 C.F.R. § 1.28(b): (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification is required if the change is to another small entity.

☒ 37 C.F.R. § 1.492(e) and (f) (surcharge fees for filing the declaration and/or filing an English translation of an International Application later than 30 months after the priority date).

SIGNATURE OF PRACTITIONER

Reg. No.: 24,622

Clarence A. Green

(type or print name of practitioner)

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Express Mail No.: EL627511083US
Applicant(s): SINDERBY et al.
INTERNATIONAL APPLICATION NO.: PCT/CA00/00808
INTERNATIONAL FILING DATE: 7/7/00
TITLE: METHOD AND SYSTEM FOR PRODUCING A HIGHER QUALITY ELECTROMYOGRAPHIC SIGNAL FROM AN ELECTRODE ARRAY
ATTORNEY DOCKET NO.: 776-010802-US(PAR)

Box PCT
Commissioner of Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Dear Sir:

Please amend the above-identified, patent application as follows:

IN THE SPECIFICATION:

After the Title and before the first paragraph, please insert the following new paragraph:

--(New) This application claims the benefit of the earlier filed International Application No. PCT/CA00/00808, International Filing Date, 7 July 2000, which designated the United States of America, and which international application was published under PCT Article 21(2) in English as WO Publication No. WO 01/03579 A1.--

Respectfully submitted,

Clarence A. Green Reg. No.: 24,622
PERMAN & GREEN, LLP
425 Post Road, Fairfield, CT 06430
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Customer No.: 2512

4 Jan 02
Date

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11/PRTS

METHOD AND SYSTEM FOR PRODUCING A HIGHER QUALITY ELECTROMYOGRAPHIC SIGNAL FROM AN ELECTRODE ARRAY

BACKGROUND OF THE INVENTION

1. Field of the invention:

The present invention relates to a method and system for producing a higher quality electromyographic signal from signals obtained with an array of electrodes, in which the electrode-sensed signals are corrected through implementation of a weighting function.

2. Brief description of the prior art:

The physiological mechanisms which generate myoelectrical activity when a muscle contracts have been known and understood for long time. In particular, how to record electromyographic signals from muscles through an array of electrodes is a well theoretically described topic in physiology.

Although the theoretical understanding is impressive, the bio-physiological application of this theory is, in practice, still partly deficient. As of today, there is known only one standardized and automatic processing system taking into consideration factors such as electrode filtering due to changes in the position of the array of electrodes relative to the center of the electrically active region of the muscle. Application of this technique includes

limitations as to its adaptability to changes in inter-electrode distance and does not optimize the use of signals available along the electrode array with varying anatomy and inter-electrode distance.

Also, the prior art technology fails to provide for full correction of the signals obtained from electrodes of the array that are not symmetrically positioned with respect to the center of the electrically active region of the muscle.

OBJECTS OF THE INVENTION

An object of the present invention is therefore to overcome the above described drawback of the prior art by processing the electrode-sensed signals through a weighting function whose purpose is to correct these electrode-sensed signals for a distance separating the electrodes from the electrically active region of the muscle.

Another object of the present invention is to predict signals which cannot be measured through the array of electrodes.

SUMMARY OF THE INVENTION

More particularly, in accordance with the present invention, there is provided a method of producing a higher quality electromyographic signal describing myoelectrical activity of an electrically active region of a subject's muscle, comprising sensing through an array of electrodes a plurality of EMG (electromyogram) signals representative of the myoelectrical

activity of the electrically active region of the subject's muscle, applying a weighting function to the detected EMG signals and thereby producing weighted signals wherein the weighting function contains correction features for the relative locations of the electrically active region and the electrodes, and combining the weighted signals and thereby producing the higher quality electromyographic signal.

The present invention further relates to a system for producing a higher quality electromyographic signal describing myoelectrical activity of an electrically active region of a subject's muscle, comprising an array of electrodes for sensing a plurality of EMG signals representative of the myoelectrical activity of the electrically active region of the subject's muscle, a weighting filter applied to the detected EMG signals to produce weighted signals wherein the weighting filter contains correction features for the relative locations of the electrically active region and the electrodes, and a combiner of the weighted signals wherein the combined weighted signals constitute the higher quality electromyographic signal.

In accordance with preferred embodiments of the present invention:

- the electrically active region of the subject's muscle comprises a center, the electrodes are separated from the center of the electrically active region by respective distances, the electrodes are separated from each other by an inter-electrode distance, and the weighting function comprises correction features for:
    - the relative location of the center of the electrically active region and the electrodes;
    - the distance separating the center of the electrically active region and the electrodes;
    - the size of the electrically active region; and

– the inter-electrode distance;

- the weighting function comprises correction features for both cancellation and distance damping effects;

- the electrically active region of the subject's muscle comprises a center, the array of electrodes comprises a series of electrodes with an inter-electrode distance, each EMG signal is detected through at least two electrodes of the array, and applying the weighting function comprises:

detecting the position of the center of the electrically active region about the array of electrodes;

relating the weighting function to the position of the center of the electrically active region with respect to the electrodes of the series;

weighting each EMG signal by means of the weighting function related to the position of the center of the electrically active region with respect to the electrodes of the series;

- the series of electrodes has a center and, when the center of the electrically active region is offset with respect to the center of the series of electrodes:

a larger number of EMG signals are detected by the electrodes on one side of the center of the electrically active region than on the other side of that center of the electrically active region so that EMG signals are missing on the above mentioned other side; and

weigthing of the EMG signals comprises replacing the missing EMG signals on the said other side by

corresponding EMG signals from the said one side, and subsequently weighting the replacement EMG signals;

- combining the weighted signals comprises adding a feature of the weighted signals together or calculating a mean of a feature of the weighted signals;

- the method and system further comprise, prior to combining the weighted signals, evaluating electromyographic quality of the weighted signals;

- evaluating electromyographic quality comprises applying to the weighted signals quality indexes for detection of at least one of the following parameters:
  - signal-to-noise ratio;
  - maximum-to-minimum drop in power density;
  - power spectrum deformation;
  - electrical activity related to electrocardiogram/esophageal peristalsis;

- evaluating electromyographic quality comprises adding to each other two of the weighted signals detected through respective electrodes situated on opposite sides of the center of the electrically active region to produce a corresponding addition signal, subtracting these two weighted signals from each other to produce a corresponding subtraction signal, and comparing these addition and substration signals, this comparison being representative of the electromyographic quality of the weighted signals;

- the method and system further comprise, prior to combining the weighted signals, replacing the weighted signals whose evaluated quality is insufficient; and

- the method and system comprise replacing the weighted signals whose evaluated quality is insufficient either by predicted values or by a last value of the weighted signals considered as containing electromyographic information; and

- the method and system comprise replacing the higher quality electromyographic signal in response to weighted signals of insufficient quality.

The objects, advantages and other features of the present invention will become more apparent upon reading of the following non restrictive description of a preferred embodiment thereof, given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the appended drawings:

Figure 1 is a schematic representation of a set-up of an EMG analysis system;

Figure 2 is a section of oesophageal catheter on which an array of electrodes of the EMG analysis system of Figure 1 is mounted;

Figure 3 is a graph showing a set of EMG signals of the diaphragm (EMGdi signals) detected by pairs of successive electrodes of the array of Figure 2;

Figure 4 is a flow chart illustrating the operation of a preferred embodiment of the method and system according to the invention, for producing a higher quality electromyographic signal describing the myoelectrical activity of a muscle;

Figure 5 is a graph showing the distribution of correlation coefficients calculated for determining the position of the center of an electrically active region (EARdi center) of the diaphragm of a subject along the array of electrodes of Figure 2;

Figure 6 is a schematic diagram illustrating the concept embodied by the method and system according to the present invention;

Figure 7 illustrates an exemplary weighting function related to the EMGdi signals collected through the array of electrodes of Figure 2;

Figure 8a is a first graph showing the gain values of a weighting function **W(n)** associated with the various pairs of electrodes of the array, when the center of the electrode array symmetrically overlies the EARdi center and the EARdi center is centered between a pair of electrodes;

Figure 8b is a second graph showing the gain values of a weighting function **W(n)** associated with the various pairs of electrodes of the array, when the center of the electrode pair is shifted with respect to the EARdi center by a distance smaller than 0.5 inter-electrode distance, and the EARdi center is located between the electrodes of the central pair of the electrode array;

Figure 8c is a third graph showing the gain values of a weighting function **W(n)** associated with the various pairs of electrodes of the array, when the center of the array is shifted with respect to the EARdi center by a distance equal to 0.5 inter-electrode distance and the EARdi center overlies an electrode common to both the central electrode pair and another adjacent electrode pair;

Figure 8d is a fourth graph showing the gain values of a weighting function **W(n)** associated with the various pairs of electrodes of the array, when the center of the array is shifted with respect to the EARdi center by a distance between 0.5 and 1.5 inter-electrode distance;

Figure 8e is a fifth graph showing the gain values of a weighting function W(n) associated with the various pairs of electrodes of the array, when the center of the array is shifted with respect to the EARdi center but the EARdi center is centered between a pair of electrodes as in Figure 8a, and two missing EMGdi signals are predicted;

Figure 8f is a sixth graph showing the gain values of a weighting function W(n) associated with the various pairs of electrodes of the array, when the center of the array is shifted with respect to the EARdi center by a distance smaller than 0.5 inter-electrode distance as in Figure 8b, the EARdi center is located but not centered between a pair of electrodes, and two missing EMGdi signals are predicted;

Figure 8g is a seventh graph showing the gain values of a weighting function W(n) associated with the various pairs of electrodes of the array, when the center of the array is shifted with respect to the EARdi center, the EARdi center overlies an electrode of the array as in Figure 8c, and two missing EMGdi signals are predicted;

Figure 9 is a graph showing measured and predicted electrode filtering effects along an array of electrodes such as that shown in Figure 2;

Figure 10 is another graph showing measured electrode filtering effects along an array of electrodes comprising overlapping pairs of electrodes;

Figure 11 is a further graph showing measured electrode filtering effects along the array of electrodes of Figure 2 for an inter-electrode distance of 5 mm; and

Figure 12 is still further a graph showing measured electrode filtering effects along the array of electrodes of Figure 2 for an inter-electrode distance of 10 mm.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Electromyographic signals produced by a muscle can be detected by means of an array of electrodes passing through the center of the muscle electrically active region. The EMG signals detected through the electrodes comprise electromyographic and noise components; and the position of the center of the electrically active region of the muscle can be detected through a reversal of polarity of the electromyographic components of the electrode-sensed EMG signals provided that the polarity of the electrode pairs is consistent from one end to the other of the electrode array.

Although the preferred embodiment of the present invention will be described in relation to an electromyographic signal produced by the

diaphragm of a subject, it should be kept in mind that it is within the scope of the present invention to process a signal representative of the myoelectrical activity of a muscle other than the diaphragm.

According to the preferred embodiment of the present invention, myoelectrical activity of the diaphragm 11 of a human subject 14 is measured through an array of electrodes such as 12 (Figures 1 and 2) mounted on the free end section 15 of an oesophageal catheter 13. As better illustrated in Figure 2, the electrodes 12 are separated by an inter-electrode distance **d**. Figure 1 shows that the catheter 13 is introduced into the subject's oesophagus through one nostril or the mouth until the array of electrodes 12 is situated at the level of the gastroesophageal junction.

An electrode 12 can be mounted on the free end section 15 of the catheter 13 by winding stainless steel wire (not shown) around that catheter 13. The wound stainless steel wire presents a rough surface smoothed out by solder, which in turn is electroplated with nickel, copper and then gold or silver. Of course, it is within the scope of the present invention to use other electrode structures. Also, the electrodes 12 can possibly be applied to a nasogastric feeding tube (not shown) which is routinely introduced in intensive-care unit (ICU) patients.

Electric wires (not shown) interconnect each pair of successive electrodes such as 1-7 (Figure 2) with a respective one of a group of differential amplifiers 16. Obviously, these electric wires follow the catheter 13 from the respective electrodes 12 to the corresponding amplifiers 16, and are preferably integrated to the catheter 13. Preferably, the electric wires transmitting the EMGdi signals (EMG signals from the diaghragm) collected by the various pairs 1-7 of electrodes 12 are shielded to reduce the influence of external noise, in particular disturbance from the 50 or 60 Hz current and voltage of the elecric mains.

The group of differential amplifiers 16 amplifies and band-pass filters each EMGdi signal. This subtraction step can also be carried out in the personal computer 19 when the amplifiers 16 are single-ended or equivalently designed amplifiers (monopolar readings).

In the example illustrated in Figures 1 and 2, the free end section 15 of the catheter 13 is provided with an array of eight electrodes 12 defining seven pairs 1, 2, 3, 4, 5, 6 and 7 of successive electrodes 12 respectively collecting seven different EMGdi signals. Although it has been found that myoelectrical activity of the diaphragm can be measured accurately with an oesophageal catheter 13 provided on the free end section 15 thereof with an array of eight electrodes 12, a different number and/or configuration of pairs of electrodes 12 can be contemplated depending on the subject's anatomy and movement of the diaphragm. Also, the pairs 1-7 do not need to be pairs of successive electrodes; they can be overlapping pairs of electrodes or can present any other configuration of electrode pairs.

A major problem in recording EMGdi signals is to maintain the noise level as low and as constant as possible. Since the electric wires transmitting the EMGdi signals from the electrodes 12 to the differential amplifiers 16 act as an antenna, it is crucial, as indicated in the foregoing description, to shield these electric wires to thereby protect the EMGdi signals from additional artifactual noise. Also, the package enclosing the differential amplifiers 16 is preferably made as small as possible (miniaturized) and is positioned in close proximity to the subject's nose to decrease as much as possible the distance between the electrodes 12 and the amplifiers 16.

The amplified EMGdi signals are sampled by a personal computer 19 through respective isolation amplifiers of a unit 18, to form signal segments of fixed duration. Unit 18 supplies electric power to the various electronic components of the differential and isolation amplifiers while

ensuring adequate isolation of the subject's body from such power supply. The unit 18 also incorporates bandpass filters included in the respective EMGdi signal channels to eliminate the effects of aliasing. The successive EMGdi signal segments are then digitally processed into the personal computer 19 after analog-to-digital conversion thereof. This analog-to-digital conversion is conveniently carried out by an analog-to-digital converter implemented in the personal computer 19. The personal computer 19 includes a monitor 40 and a keyboard 31.

It is believed to be within the capacity of those of ordinary skill in the art to construct suitable differential amplifiers 16 and an adequate isolation amplifiers and power supply unit 18. Accordingly, the amplifiers 16 and the unit 18 will not be further described in the present specification.

An example of the seven EMGdi signals collected by the pairs 1-7 of successive electrodes 12 (Figures 1 and 2) and supplied to the computer 19 is illustrated in Figure 3.

Step 401:

The first operation (step 401 of Figure 4) performed by the computer 19 is a filtering operation to remove from all the EMGdi signals of Figure 3 electrode motion artifacts, cardiac activity, electrical activity related to esophageal peristalsis, 50 and 60 Hz interference from the electric network, and high frequency noise. Implementation of such filtering is believed to be within the capacity of those of ordinary skill in the art and, accordingly, will not be further described.

Steps 402 and 403:

As the diaphragm is generally perpendicular to the longitudinal axis of the oesophageal catheter 13 equipped with an array of electrodes 12, only a portion of the electrodes 12 are situated in the vicinity of the diaphragm. It is therefore important to determine the position of the diaphragm with respect to the oesophageal electrode array. Also, the diaphragm moves during breathing and the method and system according to the invention accounts for this movement of the diaphragm.

The portion of the crural diaphragm 11 which forms the muscular tunnel through which the oesophageal catheter 13 is passed is referred to the "diaphragm electrically active region" (EARdi). The thickness of the EARdi is 20-30 mm. It can be assumed that, within the EARdi, the distribution of active muscle fibers has a center from which the majority of the EMGdi signals originate, i.e. the "diaphragm electrically active region center" (EARdi center). Therefore, when the polarity of the recordings is consistent from one end of the electrode array to the other, EMGdi signals detected on opposite sides of the EARdi center will be reversed in polarity with no phase shift; in other words, EMGdi signals obtained along the electrode array become reversed in polarity at the EARdi center.

Moving centrally from the boundaries of the EARdi, EMGdi power spectrums progressively attenuate and enhance in frequency. Reversal of signal polarity on either side of the electrode pair 4 with the most attenuated power spectrum confirms the position from which the EMGdi signals originate, the EARdi center.

Referring to Figure 4, another function of the computer 19 is to determine the position of the EARdi center along the array of electrodes 12. The EARdi center is repeatedly updated, that is re-determined at predetermined time intervals.

For that purpose, the EMGdi signals are cross-correlated in pairs in step 402 to calculate cross-correlation coefficients **r** in step 403. As well known to those of ordinary skill in the art, cross-correlation is a statistical determination of the phase relationship between two signals and essentially calculates the similarity between two signals in terms of a correlation coefficient **r**. A negative correlation coefficient **r** indicates that the cross-correlated signals are of opposite polarities.

Figure 5 shows curves of the value of the correlation coefficient **r** versus the midpoint between the pairs of electrodes from which the correlated EMGdi signals originate. In this example, the inter-electrode distance is 10 mm. Curves are drawn for distances between the correlated pairs of electrodes 12 of 5 mm (curve 20), 10 mm (curve 21), 15 mm (curve 22) and 20 mm (curve 23). One can appreciate from Figure 5 that negative correlation coefficients **r** are obtained when EMGdi signals from respective electrode pairs situated on opposite sides of the electrode pair 4 are cross-correlated. It therefore appears that the change in polarity occurs in the region of electrode pair 4, which is confirmed by the curves of Figure 3. Accordingly, it can be assumed that the EARdi center is situated substantially midway between the electrodes 12 forming pair 4.

Step 404:

In step 404, the correlation coefficients are systematically compared to determine the EARdi center. For example, the EARdi center can be precisely determined by interpolation using a square law based fit of the three most negative correlation coefficients of curve 21 obtained by successive cross-correlation of the EMGdi signal segments from each electrode pair to the EMGdi signal segments from the second next electrode pair. The EARdi center is associated to a pair of electrodes 12 to provide a

"reference position". In the illustrated example, the EARdi center is associated to pair 4 of electrodes 12.

As mentioned in the foregoing description, the position of the EARdi center along the array of electrodes 12 is continuously updated, i.e. re-calculated at predetermined time intervals overlapping or not.

Step 405:

Each EMGdi signal obtained on either side of the EARdi center is processed, more specifically multiplied/divided/added/subtracted by a weighting function. More specifically, a given parameter of the EMGdi signal is multiplied/divided/added/subtracted by the weighting function. This given parameter may comprise a feature such as, for example, an amplitude, power, area under the rectified signal, etc.

The weighting function can be derived from a mathematical model capable of adjusting each EMGdi signal in relation to the relative position of the array of electrodes 12 with respect to the EARdi center. The weighting function can also be obtained from weighting-function-describing data measured on the subject's body, for example by measuring EMGdi signals along the electrode array with knowledge of the position of the EARdi center. Finally the weighting function can be derived from both the mathematical model and the weighting function describing data measured on the subject's body. Also, the processing can be performed in the time domain or in the frequency domain.

The weighting function contains correction for:

- the relative location of the EARdi center with respect to the pairs of electrodes through which the EMGdi signals are obtained;

- the distance separating the EARdi center from the electrodes;
- the size of the electrically active region (EARdi) of the diaphragm; and
- the inter-electrode distance.

Knowing the position of the center of the electrically active region of the diaphragm (EARdi) about the array or electrodes, the mathematical model can produce weighting functions correcting for both cancellation effects and distance damping effects.

For the purpose of illustrating this concept, let's consider Figure 6 in which wanted signals **S** from a wanted signal source 601 and disturbance signals **D** from disturbances 602 are detected through an array of electrodes 603. The array of electrodes comprises **N** electrodes labeled **n**, where **n** = 1, 2, 3, 4 ... **N**. The array of electrodes does not have to be linearly arranged; any configuration is possible.

The signal detected through a given electrode **n** depends on 1st) the properties of the sources 601 and 602 (point sources or line sources with particular direction or curved line sources) and 2nd) the distances $r_s(n)$ and $r_d(n)$, respectively, between the sources 601 and 602 and the electrode **n**. Line source signals display a mixed frequency and distance dependent damping essentially described by modified bessel functions while point source signals are damped inversely proportional to the distance and independent of frequency.

The signal from each electrode is processed through the weighting function **W(n)**, which is a weighting filter which may be positive,

negative or even equal to zero prior to a summation of all contributions (**n** = 1 to **N**) to give the output signal.

The following relations describe signal conditioning in the spectral domain:

the signal **u(n)** at the given electrode **n** is

$$u(n) = S\, f_s[r_s(n)] + D\, f_d[r_d(n)] \qquad (1)$$

the output signal **Out 604** is:

$$Out = \sum_{n=1}^{N} u(n)\, W(n) \qquad (2)$$

Combining the two equations and rearranging the terms give the following expression:

$$Out = S \sum_{n=1}^{N} f_s[r_s(n)]\, W(n) + D \sum_{n=1}^{N} f_d[r_d(n)]\, W(n) \qquad (3)$$

where f_s and f_d are functions describing damping and/or other alteration (such as interference) to the signal as a function of distances r_s and r_d, respectively.

Figure 7 is a graph illustrating an example of weighting function **W(n)**. As can be seen the graph of Figure 7 relates the weighting function **W(n)** to the position of the pairs of electrodes from which the EMGdi signals of Figure 3 originate, and the center of the EARdi determined through the correlation coefficients **r** in steps 402-404.

In Figure 7, curve 701 illustrating the weighting function **W(n)** shows that signals from electrode pairs 1, 2, 3, 4, 5, 6 and 7 are represented by

respective local gain values of the weighting function **W(n)**. The local gain values for all electrode pairs is determined by the position of the EARdi center along the array of electrodes. More specifically, the local gain value of electrode pair 4 is the gain value of curve 701 determined by the position of the EARdi center itself centered between the electrodes of pair 4 (see dashed line 702). The local gain value of electrode pairs 1, 2, 3, 5, 6 and 7 is the gain value of curve 701 at positions shifted from the EARdi center by a corresponding number of inter-electrode distances (see dashed lines 703-708). In the illustrated example, the signal from electrode pair 1 will be represented by gain value 0.05 (dashed line 703), the signal from electrode pair 2 will be represented by gain value 0.3 (dashed line 704), the signal from electrode pair 3 will be represented by gain value 0.9 (dashed line 705), the signal from electrode pair 4 will be represented by gain value 0.3 (dashed line 702), the signal from electrode pair 5 will be represented by gain value 0.9 (dashed line 706), the signal from electrode pair 6 will be represented by gain value 0.3 (dashed line 707), and the signal from electrode pair 7 will be represented by gain value 0.05 (dashed line 708).

In general terms, for a good performance, the first term of Equation 3 should be maximized and the second term minimized, or depending on the application of concern, known filtering strategies should be used to optimize the spectral distributions of wanted and disturbance signals. The optimization is performed by varying sign, strength, and spectral (complex) contents of the weighting filter W(n). This process can be guided by a priori knowledge of the type of signal source (line, point, etc.) and the corresponding type of damping (modified bessel functions, inverse distance damping, etc.) and/or experimental knowledge of the signals spectral content.

Figures 8a-8c are graphs showing the effect of moving the EARdi center along the array of electrodes from a position in which the EARdi center is located centrally between a pair of electrodes to a position in which the

EARdi center overlies an electrode. These graphs clearly show how the signal amplitudes along the array of electrodes are affected by alteration of the position of the EARdi center with respect to the electrode pair 4.

The graph of Figure 8a shows the gain values of the weighting function **W(n)** associated with the various pairs of electrodes of the array, when the center of the electrode array symmetrically overlies the EARdi center and the EARdi center is centered between the central electrode pair 4. The position of the EARdi center is the same as illustrated in Figure 7. In Figure 8a, electrode filtering is symmetrical and presents cancellation at electrode pair 4.

The graph of Figure 8b illustrates the gain values of a weighting function **W(n)** associated with the various pairs of electrodes of the array, when the center of the array is shifted with respect to the EARdi center by a distance smaller than 0.5 inter-electrode distance. More specifically, in Figure 8b, the EARdi center is moved (upwardly in the figure) by 25% of the inter-electrode distance. In this example, the weighting function is skewed, but there is still some cancellation at electrode pair 4.

Figure 8c is a third graph showing the gain values of a weighting function **W(n)** associated with the various pairs of electrodes of the array, when the center of the array is shifted with respect to the EARdi center by a distance equal to 0.5 inter-electrode distance and the EARdi center is centered on an electrode. The resulting weighting function is symmetrical with no cancellation at electrode pair 4.

The above Figures 8a, 8b and 8c show three (3) possible locations of the EARdi center relative to an electrode pair centered on the electrode array. The fourth figure, namely Figure 8d, exemplifies the behavior of the signals if the EARdi center continues to move over to an adjacent electrode

pair. In this latter case, the gain values are the same as in Figure 8b but are reversed.

Figures 8e, 8f and 8g show the same positional shifts as in Figures 8a, 8b and 8c but when the EARdi center is located at electrode pair 2 instead of central electrode pair 4. The EMGdi signals corresponding to weighting function gain values **W(n+2)** and **W(n+3)** then fall outside of the electrode array. The missing weighted signals can then be predicted by using the same EMGdi signal detected at electrode pairs 4 and 3 processed through the weighting function. These predicted values are then used in the calculation for the total signal strength across the electrode array.

In this preferred embodiment, the electrodes at the bottom of the array (Figures 8e-g) are not used. However, depending on how complex the model for prediction and computation is, these signals can also be used. If correction for signals that fall off the electrode array is not performed, it is impossible to obtain an accurate estimate of the total signal value.

Just a word to mention that the weighting function **W(n)** of the Figures 7 and 8 regards conditioning of the amplitude of the EMGdi signal and corresponds to curve 901 of Figure 9 (curve of the amplitude of the EMGdi signal in relation to the distance of the electrodes of the pair from the EARdi center). The EMGdi signals can also be frequency conditioned by constructing a weighting filter using a curve such as 902 in Figure 9 (curve of the center frequency of the EMGdi signal in relation to the distance of the electrodes of the pair from the EARdi center). A combination of frequency and amplitude conditioning can also be implemented.

Figures 10, 11 and 12 are other examples of amplitude and frequency conditioning curves that can serve as weighting functions **W(n)**.

The curves of Figures 9, 10, 11 and 12 are usually experimentally established on a sufficient number of recordings in a subject.

Step 406:

In this step, electromyographic quality of the weighted signals is evaluated.

This evaluation of the electromyographic quality of all the weighted signals can be performed for their relative electromyographic and noise components. Thus, if preferred, summation of the EMGdi signals (amplitude, area under the curve, power, etc.) along the array of electrodes can be limited to signals that contain physiological information pertaining to the diaphragm. This evaluation of signals content can be performed by applying well known signal quality indexes for detection of signal-to-noise ratio, maximum-to-minimum drop in power density, power spectrum deformation, and/or electrocardiogram/esophageal peristalsis.

This evaluation of signals for their relative electromyographic and noise components can also be obtained by adding and subtracting EMGdi signals obtained on opposite sides with symmetrical position to the electrically active region center (for example signals from electrode pairs 3 and 5 in Figure 7) and comparing the results of these addition and subtraction. A first EMGdi signal detected by a pair of electrodes of the array on a first side of the center of the EARdi has an electromyographic component of a first polarity and a noise component of given polarity. A second EMGdi signal detected by another pair of electrodes of the array on the second side of the EARdi center, opposite to the first side, has an electromyographic component of a second polarity opposite to the first polarity and a noise component of said given polarity. Subtraction of the first and second EMGdi signals subtracts the noise components of the first and second EMGdi signals from each other

but adds the electromyographic components of these first and second EMGdi signals together to produce a resulting signal with high electromyographic content and low noise content. Addition of the first and second EMGdi signals adds the noise components of the first and second EMGdi signals to each other but subtracts the electromyographic components of these first and second EMGdi signals from each other to produce a signal with low electromyographic content and high noise content. Comparison of the resulting added and subtracted signals (area under the curve/power/amplitude of the signals) provides information about the relative contribution of noise and electromyographic content to the signal. Signals with a high electromyographic content will be considered as a high quality signal.

Step 407:

EMGdi signals considered as not containing physiological information (insufficient quality as determined in step 406) pertaining to the diaphragm can be replaced by predicted values or simply the last value considered to contain physiological information pertaining to the diaphragm. This replacement strategy can be applied on either each single EMGdi signal obtained from the electrode array or on the summation or mean of the weighted EMGdi signals representative for all or some of the signals obtained along the electrode array.

Step 408:

The last step consists of calculating the sum of a feature (RMS voltage, RMS current, power, RMS means amplitude, area under the curve, etc) of the eventually replaced, signal quality evaluated weighted EMGdi signals from the electrodes of the array. A mean of the rectified signals, or a

RMS or other suitable or equivalent value of these signals can be calculated as well for further use.

The resulting signal will provide improvement of the signal-to-noise ratio and minimize influence of electrode filtering due to changes in the position of the electrode array relative the muscle's electrically active region center. It also accounts for differences in anatomy between individuals and differences in inter-electrode distance and design, and for the EARdi center approaching the distal or proximal end of the array of electrodes.

Of course, the application of the present invention is not limited to the diaphragm but to any other muscle and that, for any type of array of electrodes.

Although the present invention has been described hereinabove by way of a preferred embodiment thereof, this embodiment can be modified at will, within the scope of the appended claims, without departing from the spirit and nature of the subject invention.

WHAT IS CLAIMED IS:

1. A method of producing a higher quality electromyographic signal describing myoelectrical activity of an electrically active region of a subject's muscle, comprising:

sensing through an array of electrodes a plurality of EMG signals representative of the myoelectrical activity of the electrically active region of the subject's muscle;

applying a weighting function to the detected EMG signals and thereby producing weighted signals, the weighting function containing correction features for the relative locations of the electrically active region and the electrodes; and

combining the weighted signals and thereby producing the higher quality electromyographic signal.

2. A method of producing a higher quality electromyographic signal as defined in claim 1, wherein:

the electrically active region of the subject's muscle comprises a center;

the electrodes are separated from the center of the electrically active region by respective distances;

the electrodes are separated from each other by an inter-electrode distance; and

the weighting function comprises correction features for:

– the relative location of the center of the electrically active region and the electrodes;

– the distance separating the center of the electrically active region and the electrodes;

– the size of the electrically active region; and

– the inter-electrode distance.

3. A method of producing a higher quality electromyographic signal as defined in claim 1, wherein the weighting function comprises correction features for both cancellation and distance damping effects.

4. A method of producing a higher quality electromyographic signal as defined in claim 1, wherein the electrically active region of the subject's muscle comprises a center, the array of electrodes comprises a series of electrodes with an inter-electrode distance, each EMG signal is detected through at least two electrodes of the array, and wherein applying the weighting function comprises:

detecting the position of the center of the electrically active region about the array of electrodes;

relating the weighting function to the position of the center of the electrically active region with respect to the electrodes of said series;

weighting each EMG signal by means of the weighting function related to the position of the center of the electrically active region with respect to the electrodes of said series.

5. A method of producing a higher quality electromyographic signal as defined in claim 4, wherein the series of electrodes has a center, and wherein, when the center of the electrically active region is offset with respect to the center of the series of electrodes:

a larger number of EMG signals are detected by the electrodes on one side of the center of the electrically active region than on the other side of said center of the electrically active region so that EMG signals are missing on said other side; and

weigthing of the EMG signals comprises replacing the missing EMG signals on said other side by corresponding EMG

signals from said one side and subsequently weighting said replacement EMG signals.

6. A method of producing a higher quality electromyographic signal as defined in claim 1, wherein combining the weighted signals comprises:

adding a feature of the weighted signals together.

7. A method of producing a higher quality electromyographic signal as defined in claim 1, wherein combining the weighted signals comprises;

calculating a mean of a feature of the weighted signals.

8. A method of producing a higher quality electromyographic signal as defined in claim 1, further comprising, prior to combining the weighted signals, evaluating electromyographic quality of the weighted signals.

9. A method of producing a higher quality electromyographic signal as recited in claim 8, wherein evaluating electromyographic quality comprises applying to the weighted signals quality indexes for detection of at least one of the following parameters:

- signal-to-noise ratio;
- maximum-to-minimum drop in power density;
- power spectrum deformation;
- electrical activity related to electrocardiogram/esophageal peristalsis.

10. A method of producing a higher quality electromyographic signal as recited in claim 8, wherein the electrically active

region of the subject's muscle comprises a center, and wherein evaluating electromyographic quality comprises adding to each other two of the weighted signals detected through respective electrodes situated on opposite sides of the center of the electrically active region to produce a corresponding addition signal, subtracting said two weighted signals from each other to produce a corresponding subtraction signal, and comparing said addition and substration signals, said comparision being representative of the electromyographic quality of the weighted signals.

11. A method of producing a higher quality electromyographic signal as recited in claim 8, further comprising, prior to combining the weighted signals, replacing the weighted signals whose evaluated quality is insufficient.

12. A method of producing a higher quality electromyographic signal as recited in claim 11, comprising replacing the weighted signals whose evaluated quality is insufficient by predicted values.

13. A method of producing a higher quality electromyographic signal as recited in claim 11, comprising replacing the weighted signals whose evaluated quality is insufficient by a last value of said weighted signals considered as containing electromyographic information.

14. A method of producing a higher quality electromyographic signal as recited in claim 8, comprising replacing the higher quality electromyographic signal in response to weighted signals of insufficient quality.

15. A system for producing a higher quality electromyographic signal describing myoelectrical activity of an electrically active region of a subject's muscle, comprising:

an array of electrodes for sensing a plurality of EMG signals representative of the myoelectrical activity of the electrically active region of the subject's muscle;

a weighting filter applied to the detected EMG signals to produce weighted signals, the weighting filter containing correction features for the relative locations of the electrically active region and the electrodes; and

a combiner of the weighted signals, the combined weighted signals constituting the higher quality electromyographic signal.

16. A system for producing a higher quality electromyographic signal as defined in claim 15, wherein:

the electrically active region of the subject's muscle comprises a center;

the electrodes are separated from the center of the electrically active region by respective distances;

the electrodes are separated from each other by an inter-electrode distance; and

the weighting filter comprises correction features for:

– the relative location of the center of the electrically active region and the electrodes;

– the distance separating the center of the electrically active region and the electrodes;

– the size of the electrically active region; and

– the inter-electrode distance.

17. A system for producing a higher quality electromyographic signal as defined in claim 15, wherein the weighting filter comprises correction features for both cancellation and distance damping effects.

18. A system for producing a higher quality electromyographic signal as defined in claim 15, wherein:

the electrically active region of the subject's muscle comprises a center;

the array of electrodes comprises a series of electrodes with an inter-electrode distance;

each EMG signal is detected through at least two electrodes of the array; and

the weighting filter comprises a weighting function related to the position of the center of the electrically active region with respect to the electrodes of said series.

19. A system for producing a higher quality electromyographic signal as defined in claim 15, wherein the series of electrodes has a center, and wherein, when the center of the electrically active region is offset with respect to the center of the series of electrodes:

a larger number of EMG signals are detected by the electrodes on one side of the center of the electrically active region than on the other side of said center of the electrically active region so that EMG signals are missing on said other side; and

the system comprises means for replacing the missing EMG signals on said other side by corresponding EMG signals from said one side, and means for subsequently weighting said replacement EMG signals.

20. A system for producing a higher quality electromyographic signal as defined in claim 15, wherein the combiner comprises:

an adder of a feature of the weighted signals.

21. A system for producing a higher quality electromyographic signal as defined in claim 15, wherein the combiner comprises:

a calculator of a mean of a feature of the weighted signals.

22. A system for producing a higher quality electromyographic signal as defined in claim 15, further comprising, prior to combining the weighted signals, an evaluator of an electromyographic quality of the weighted signals.

23. A system for producing a higher quality electromyographic signal as recited in claim 22, wherein the evaluator comprises means for applying to the weighted signals quality indexes for detection of at least one of the following parameters:

- signal-to-noise ratio;
- maximum-to-minimum drop in power density;
- power spectrum deformation;
- electrical activity related to electrocardiogram/esophageal peristalsis.

24. A system for producing a higher quality electromyographic signal as recited in claim 22, wherein the electrically active region of the subject's muscle comprises a center, and wherein the evaluator comprises an adder of two of the weighted signals detected through respective electrodes situated on opposite sides of the center of the electrically active region to produce a corresponding addition signal, a subtractor of said two weighted signals from each other to produce a corresponding subtraction signal, and a comparator of said addition and substration signals, this comparision being representative of the electromyographic quality of the weighted signals.

25. A system for producing a higher quality electromyographic signal as recited in claim 22, further comprising means for replacing, prior to combining the weighted signals, the weighted signals whose evaluated quality is insufficient.

26. A system for producing a higher quality electromyographic signal as recited in claim 25, comprising means for replacing the weighted signals whose evaluated quality is insufficient by predicted values.

27. A system for producing a higher quality electromyographic signal as recited in claim 25, comprising means for replacing the weighted signals whose evaluated quality is insufficient by a last value of said weighted signals considered as containing electromyographic information.

28. A system for producing a higher quality electromyographic signal as recited in claim 22, comprising means for replacing the higher quality electromyographic signal in response to weighted signals of insufficient quality.

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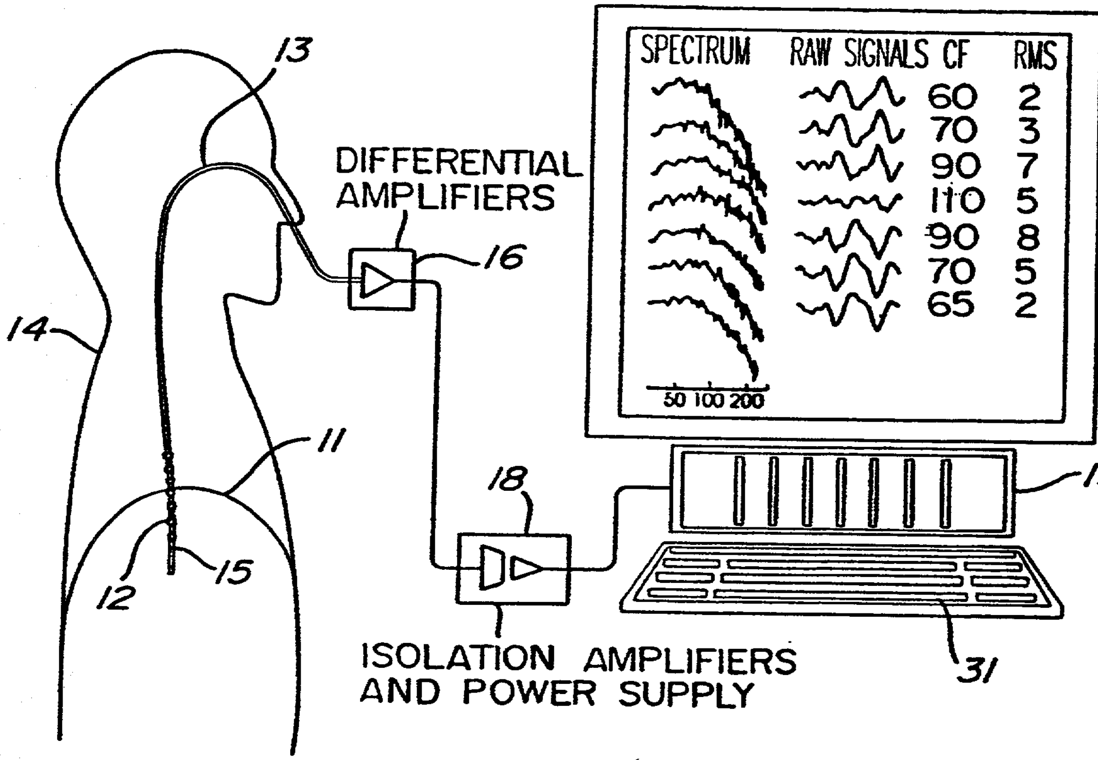

FIG. 1

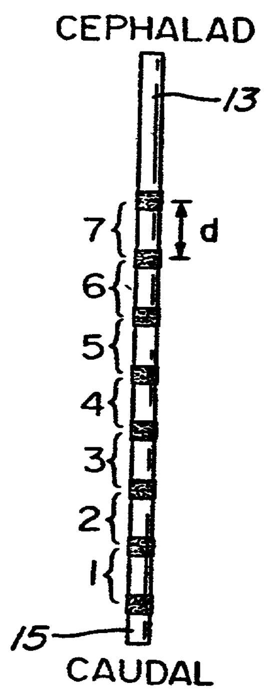

FIG. 2

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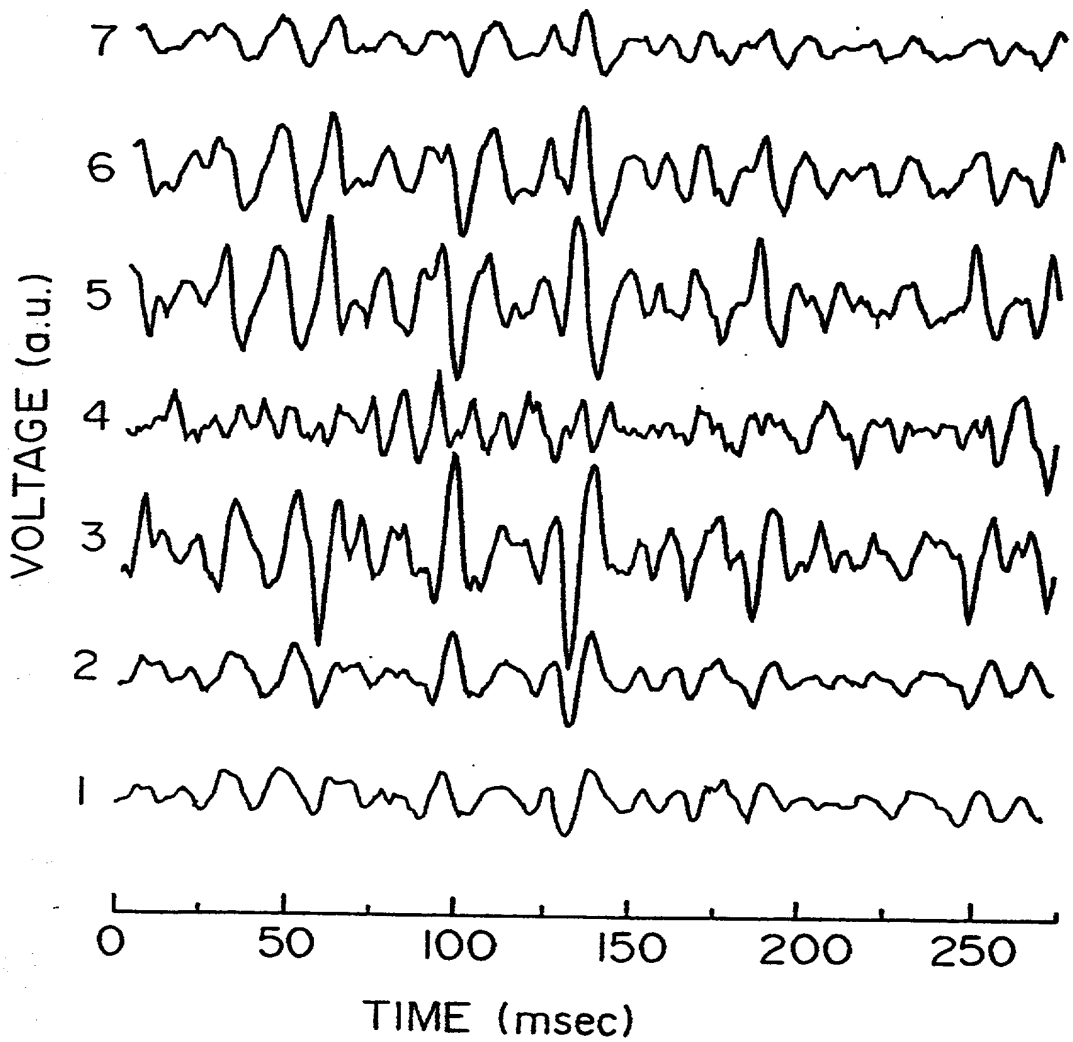

FIG-3

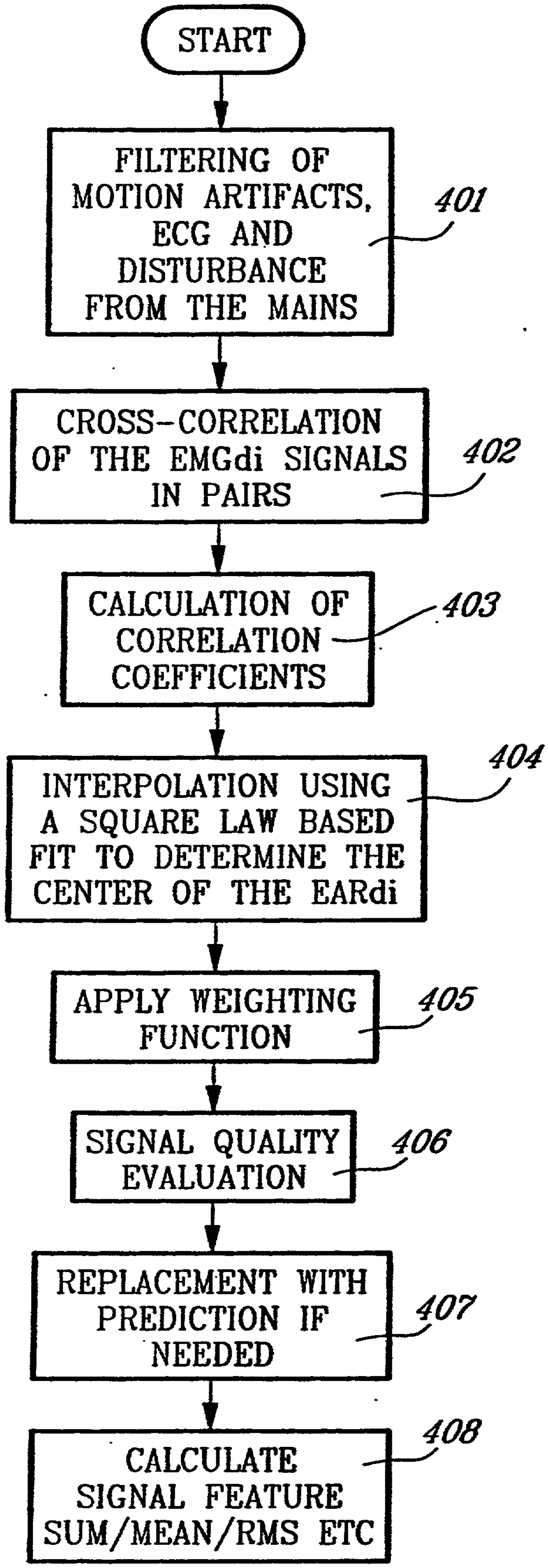
START
FILTERING OF MOTION ARTIFACTS, ECG AND DISTURBANCE FROM THE MAINS
401
CROSS-CORRELATION OF THE EMGdi SIGNALS IN PAIRS
402
CALCULATION OF CORRELATION COEFFICIENTS
403
INTERPOLATION USING A SQUARE LAW BASED FIT TO DETERMINE THE CENTER OF THE EARdi
404
APPLY WEIGHTING FUNCTION
405
SIGNAL QUALITY EVALUATION
406
REPLACEMENT WITH PREDICTION IF NEEDED
407
CALCULATE SIGNAL FEATURE SUM/MEAN/RMS ETC
408

FIG-4

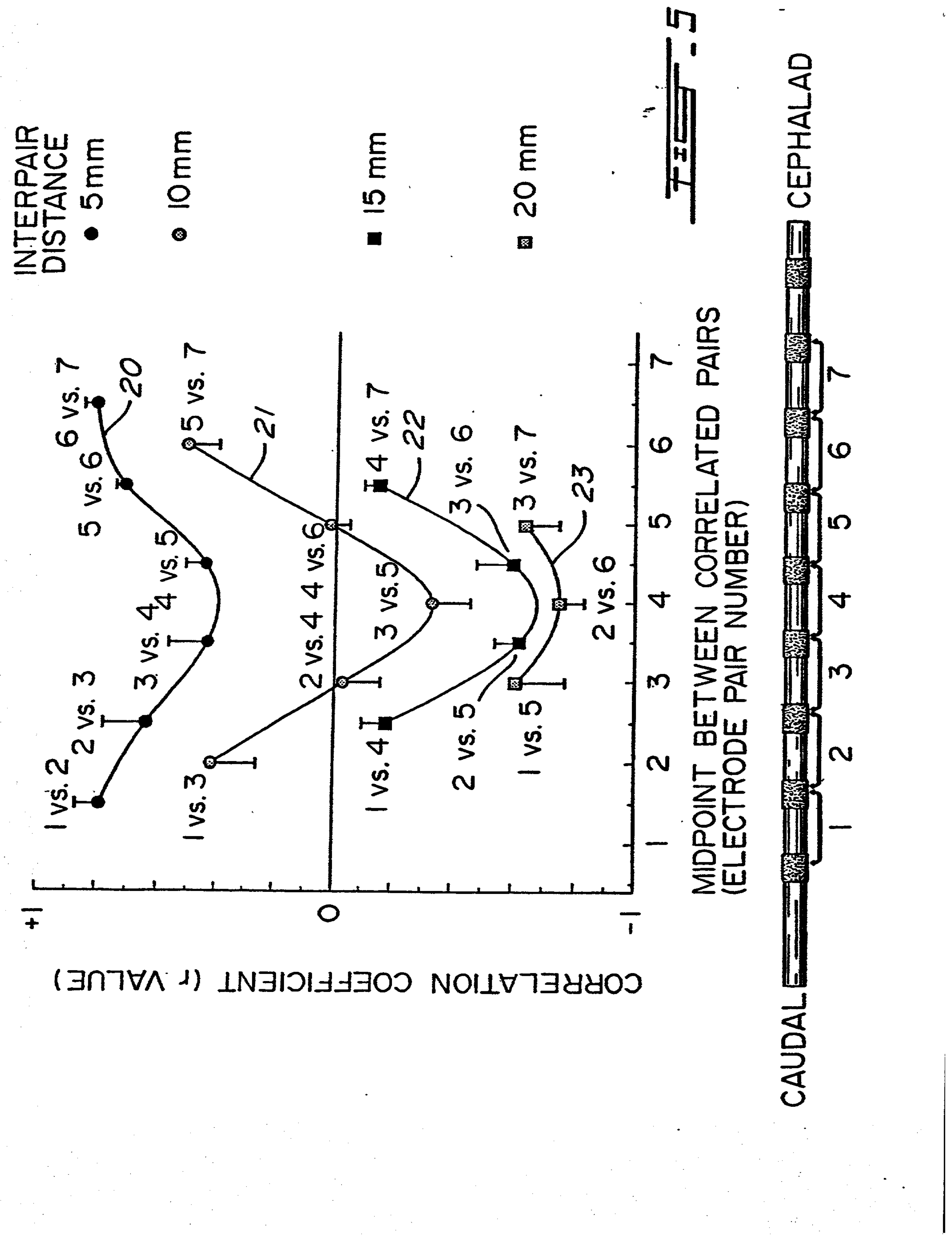
CORRELATION COEFFICIENT (r VALUE)
+1
0
-1
MIDPOINT BETWEEN CORRELATED PAIRS
(ELECTRODE PAIR NUMBER)
1
2
3
4
5
6
7
INTERPAIR
DISTANCE
5mm
10mm
15 mm
20 mm
1 vs. 2
2 vs. 3
3 vs. 4
4 vs. 5
5 vs. 6
6 vs. 7
20
1 vs. 3
2 vs. 4
3 vs. 5
4 vs. 6
5 vs. 7
21
1 vs. 4
2 vs. 5
3 vs. 6
4 vs. 7
22
1 vs. 5
2 vs. 6
3 vs. 7
23
CAUDAL
CEPHALAD

FIG. 5

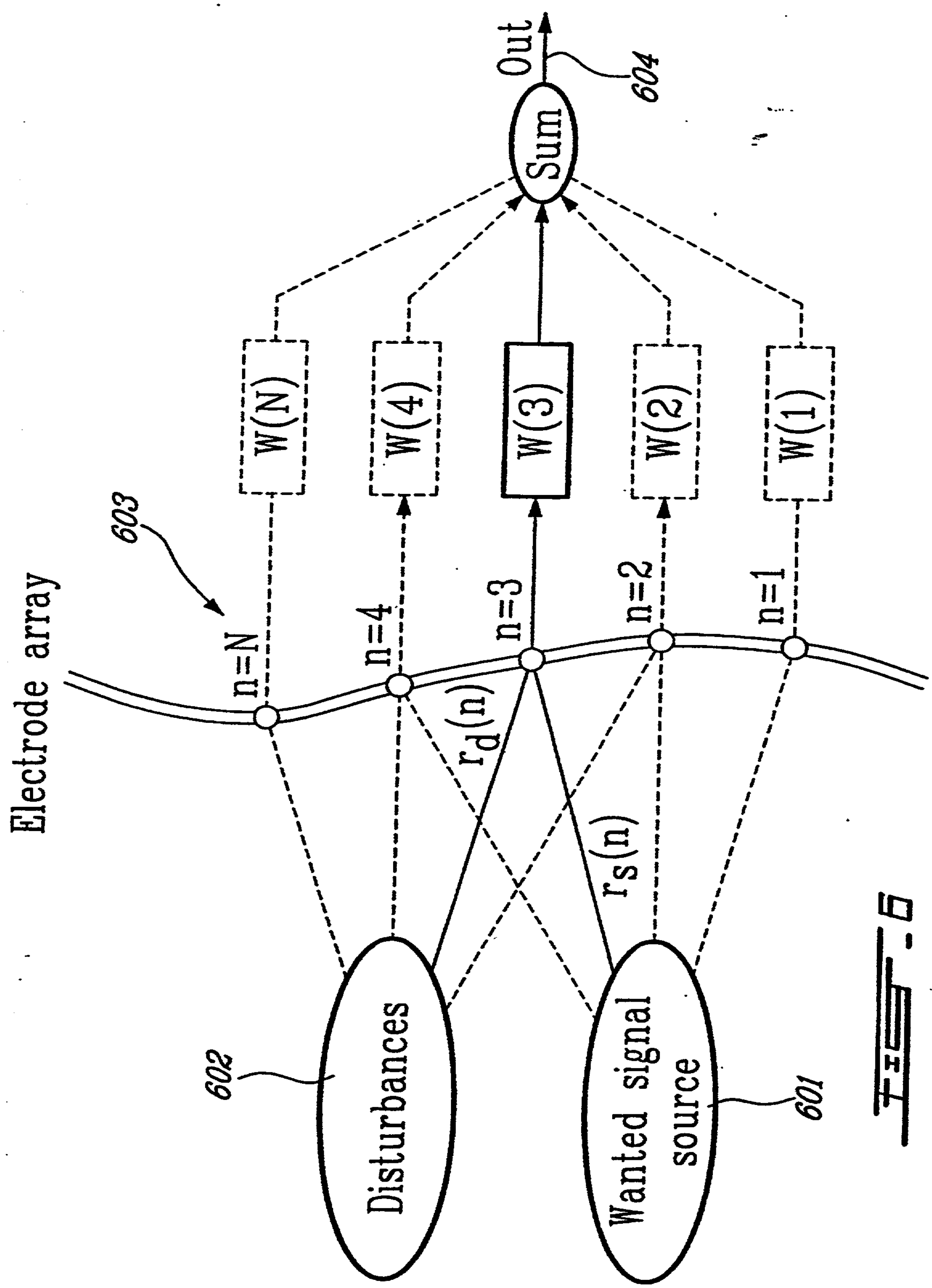
Electrode array
603
n=N
n=4
n=3
n=2
n=1
W(N)
W(4)
W(3)
W(2)
W(1)
Sum
Out
604
$r_d(n)$
$r_s(n)$
Disturbances
602
Wanted signal source
601

FIG. 6

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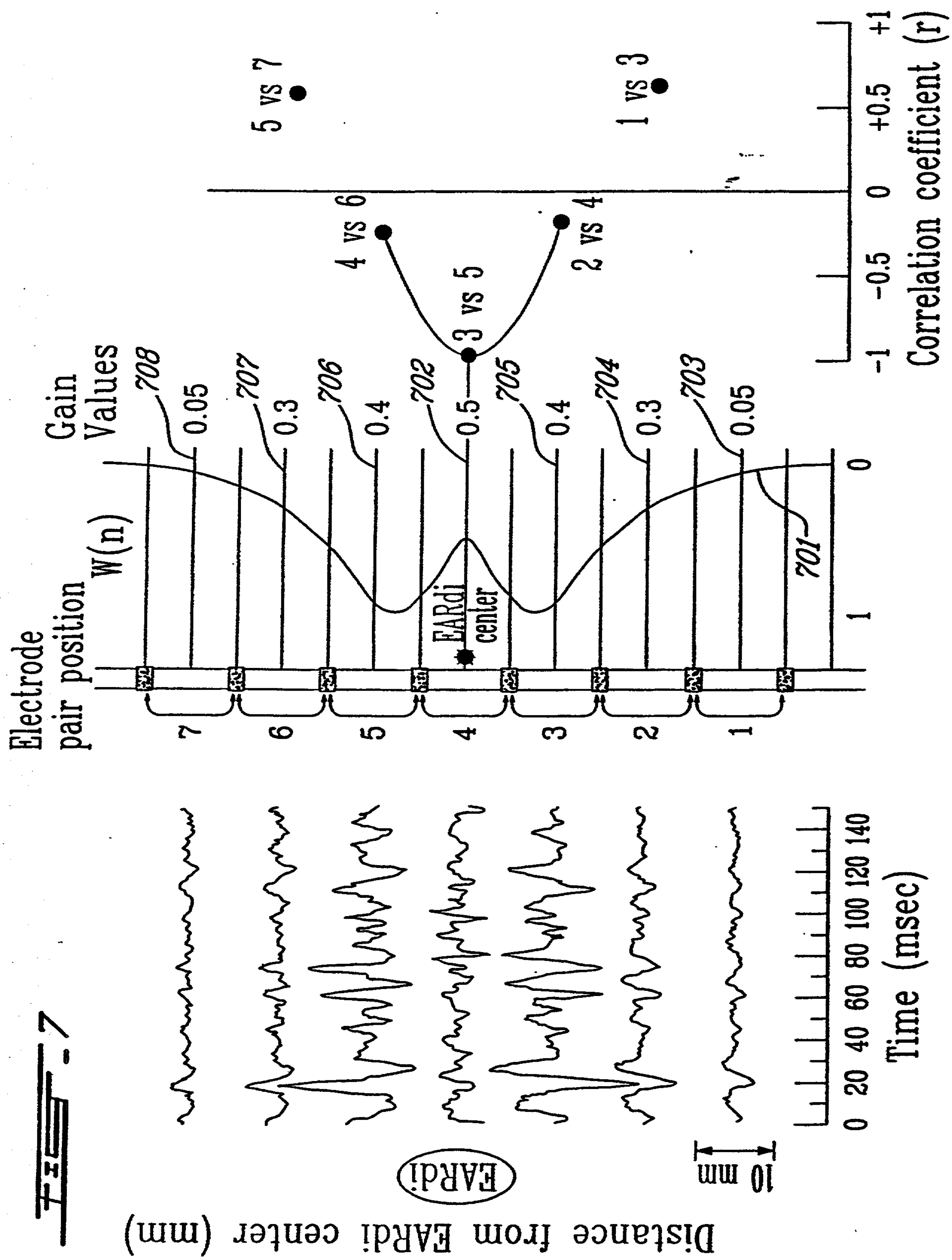

FIG. 7

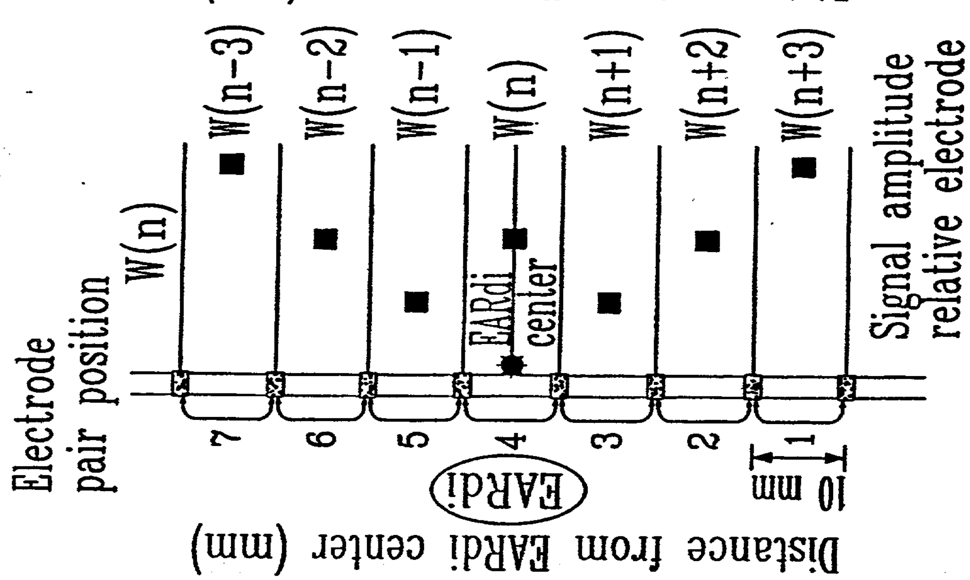

FIG. 8a

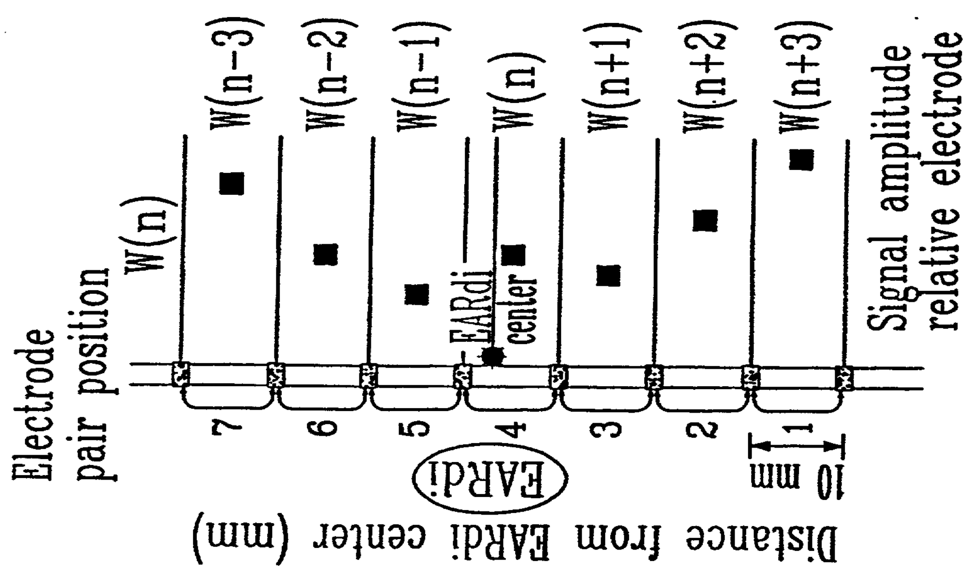

FIG. 8b

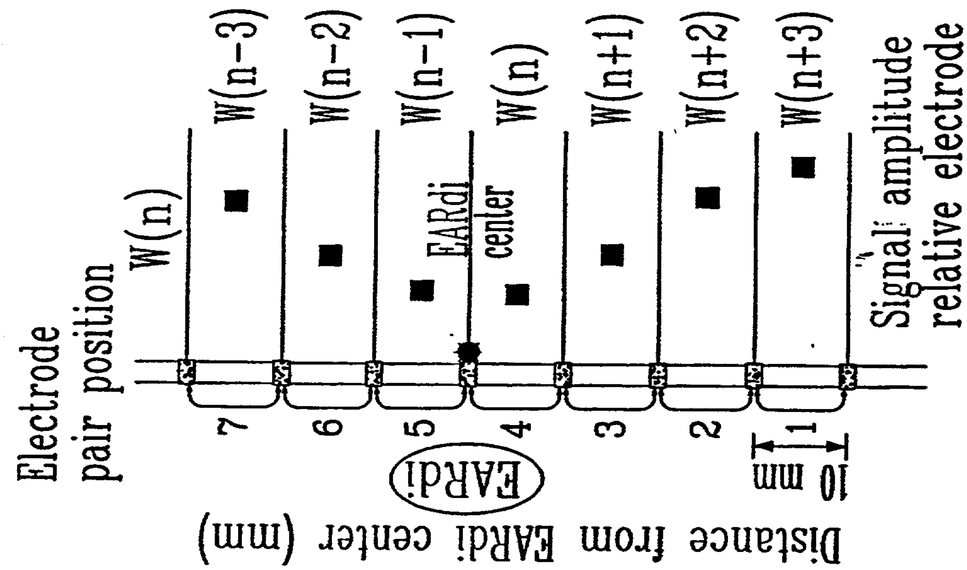

FIG. 8c

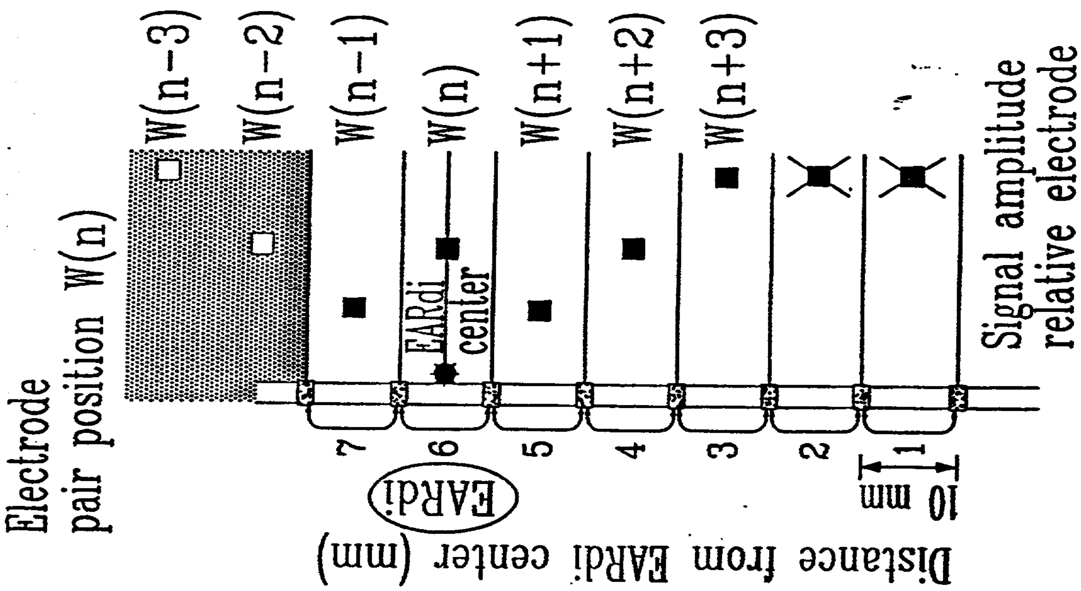
Electrode
pair position W(n)
W(n−3)
W(n−2)
W(n−1)
W(n)
W(n+1)
W(n+2)
W(n+3)
EARdi
center
7
6
5
4
3
2
1
EARdi
10 mm
Distance from EARdi center (mm)
Signal amplitude
relative electrode
pair 6

FIG. 8E

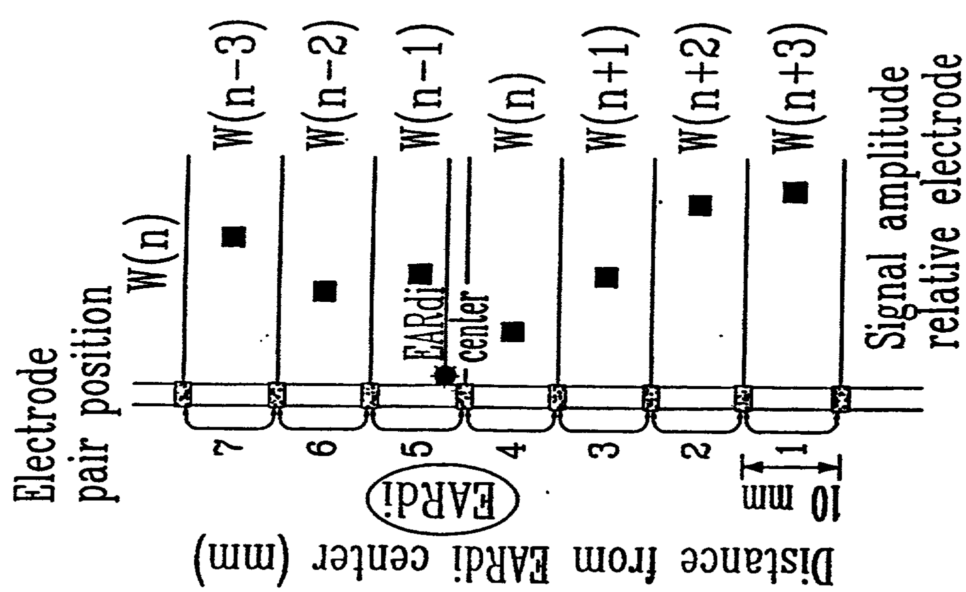
Electrode
pair position
W(n)
W(n−3)
W(n−2)
W(n−1)
W(n)
W(n+1)
W(n+2)
W(n+3)
EARdi
center
7
6
5
4
3
2
1
EARdi
10 mm
Distance from EARdi center (mm)
Signal amplitude
relative electrode
pair 4

FIG. 8D

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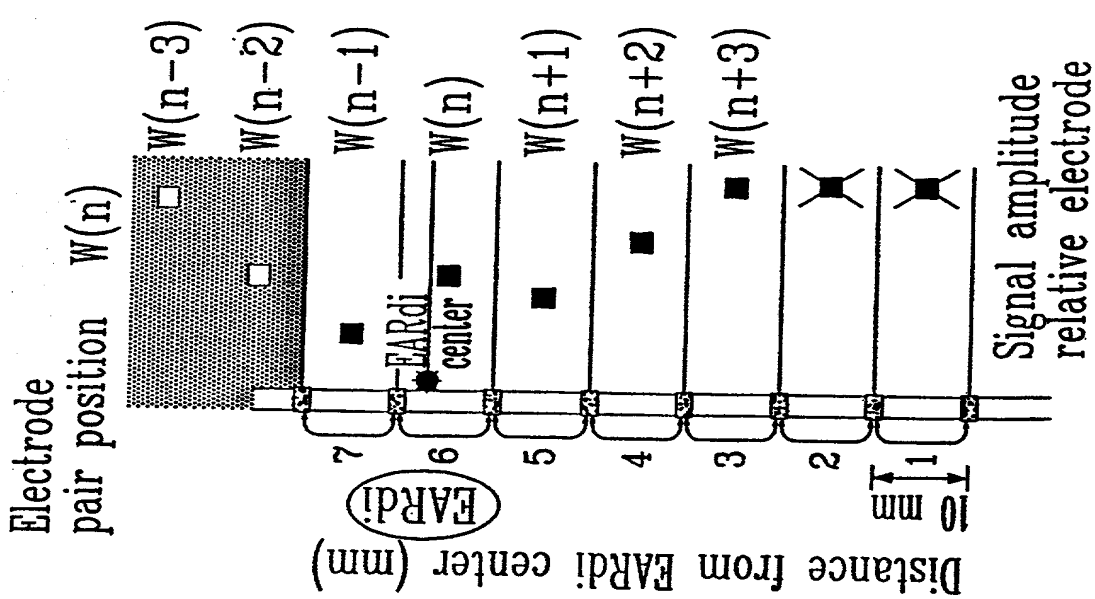

Fig. 8f

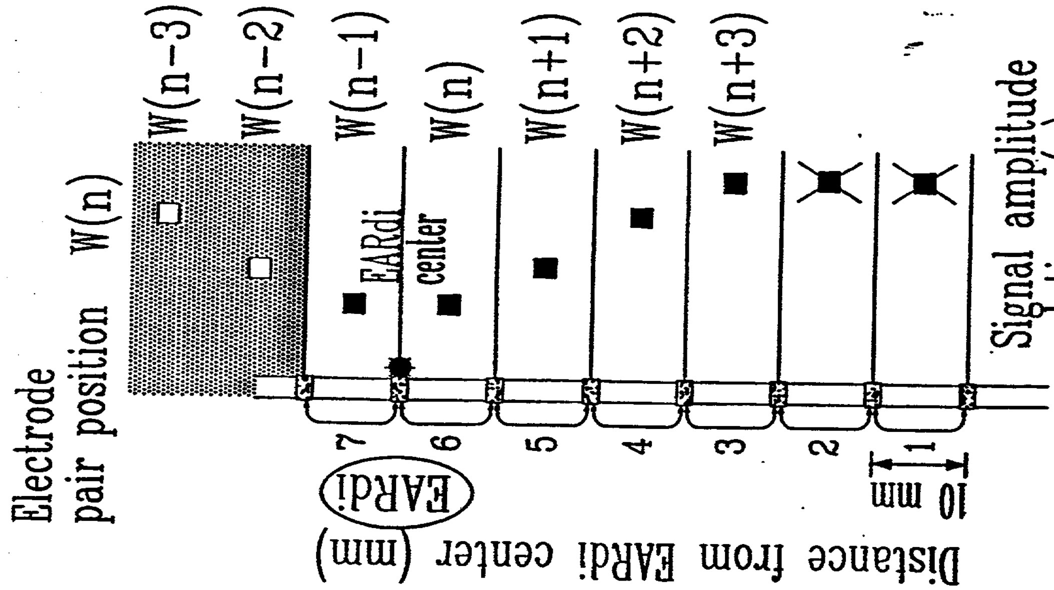

Fig. 8g

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PCT/CA00/00808

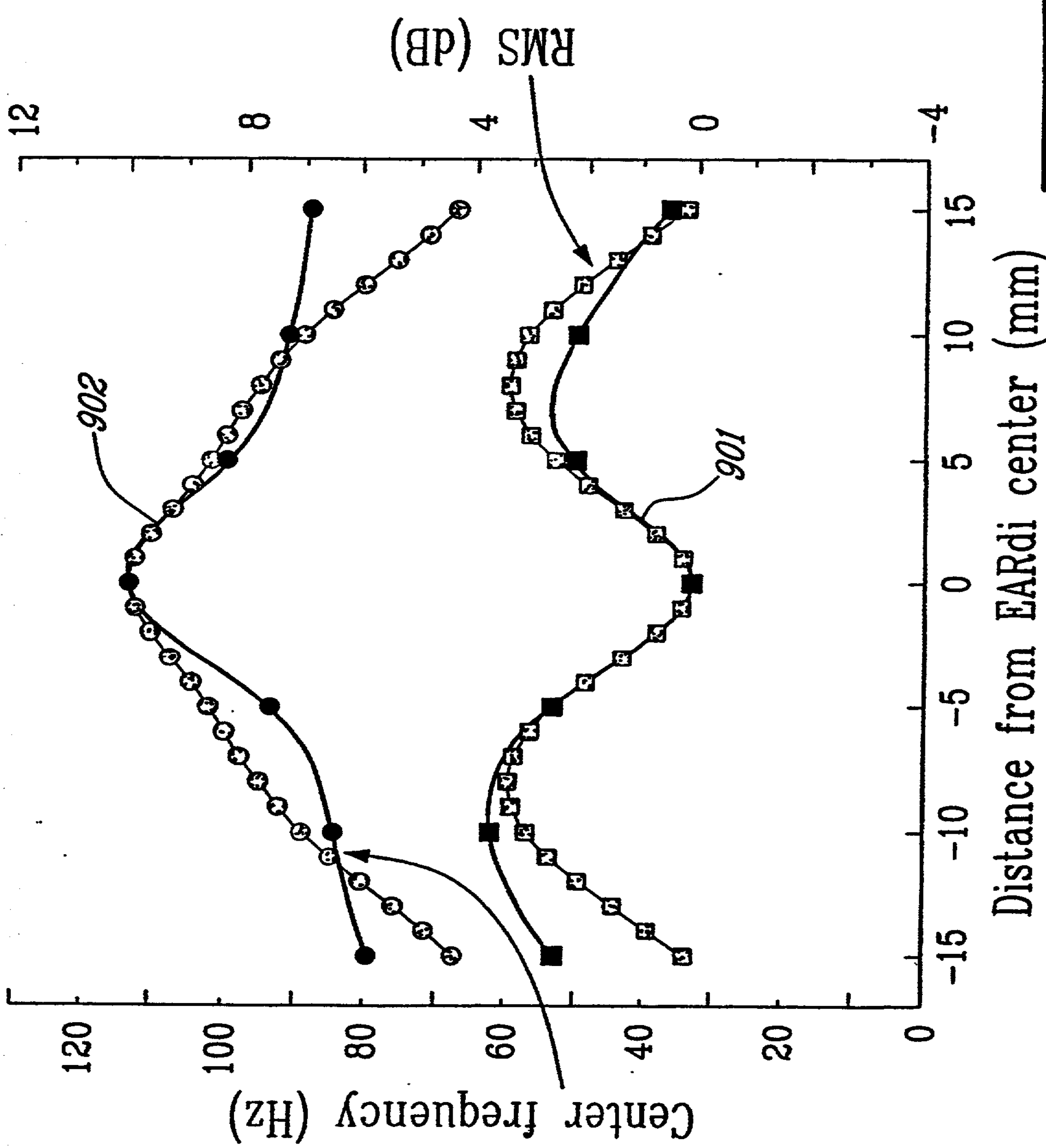

FIG. 9

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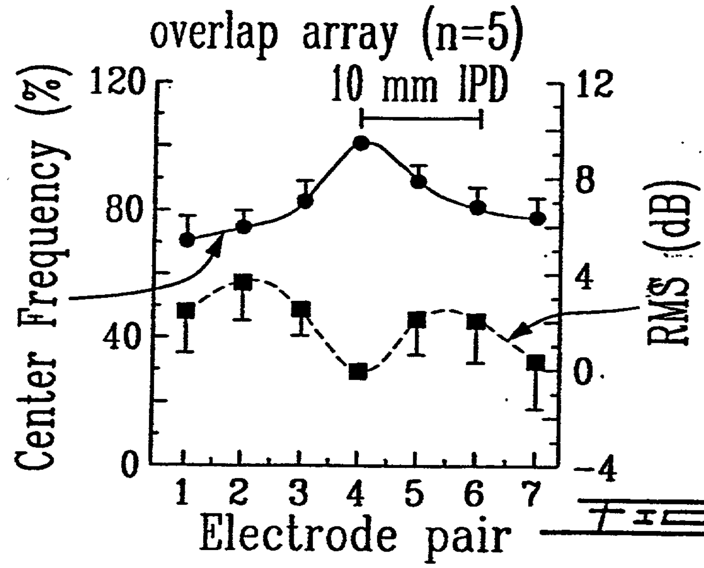

FIG. 10

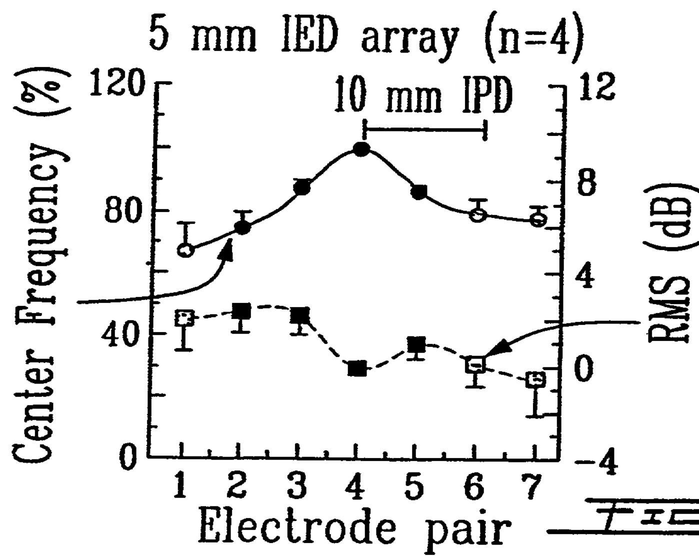

FIG. 11

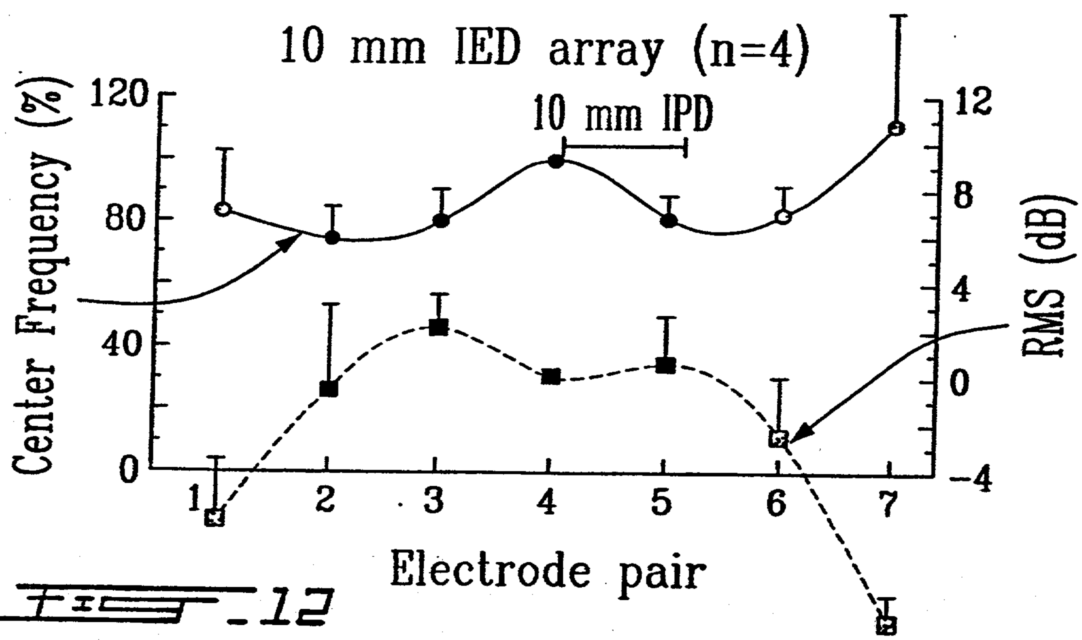

FIG. 12

#5

Docket No.: 776-010802-US(PAR)

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Title: METHOD AND SYSTEM FOR PRODUCING A HIGHER QUALITY ELECTROMYOGRAPHIC SIGNAL FROM AN ELECTRODE ARRAY

the specification of which

(check one)

☐ is attached hereto.

X was filed on as United States Application No.10/030,366 or PCT International Application Number PCT/CA00/00808 filed on July 7, 2000 and was amended on (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International Application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

(Number)	(Country)	(Day/Month/Year Filed)	Priority Not Claimed
PCT/CA00/00808	PCT	7 July 2000	☐
2,276,962	Canada	7 July 1999	☐
			☐
			☐

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.) (Filing Date)

(Application Serial No.) (Filing Date)

(Application Serial No.: (Filing Date)

I hereby claim the benefit under 35 U.S.C. Section 120 of any United States application(s), or Section 365(c) of any PCT International Application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International Application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C.F.R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.) (Filing Date) (Status) (patented, pending, abandoned)

(Application Serial No.) (Filing Date) (Status) (patented, pending, abandoned)

(Application Serial No.) (Filing Date) (Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Docket No.: 776-010802-US(PAR)

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Title: METHOD AND SYSTEM FOR PRODUCING A HIGHER QUALITY ELECTROMYOGRAPHIC SIGNAL FROM AN ELECTRODE ARRAY

the specification of which

(check one)

☐ is attached hereto.

X was filed on as United States Application No. 10/030,366 or PCT International Application Number PCT/CA00/00808 filed on July 7, 2000 and was amended on (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International Application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

(Number)	(Country)	(Day/Month/Year Filed)	Priority Not Claimed
PCT/CA00/00808	PCT	7 July 2000	☐
2,276,962	Canada	7 July 1999	☐
			☐
			☐

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.) (Filing Date)

(Application Serial No.) (Filing Date)

(Application Serial No.: (Filing Date)

I hereby claim the benefit under 35 U.S.C. Section 120 of any United States application(s), or Section 365(c) of any PCT International Application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International Application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C.F.R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

All attorneys listed under Customer No.: 2512

Send Correspondence to:

Customer No.: 2512

Direct Telephone Calls to: (name and telephone number)
Clarence A. Green, Reg. No.: 24,622 (203) 259-1800

Full name of sole or first inventor: Christer SINDERBY
Sole or first inventor's signature: DATE
Residence: 12750, 27th Avenue, Montreal, Quebec H1E 1Z9, Canada
Citizenship: Canadian
Post Office Address: 12750, 27th Avenue, Montreal, Quebec H1E 1Z9, Canada

Full name of second inventor: Jennifer BECK
Second inventor's signature: DATE
Residence address: 12750, 27TH Avenue, Montreal, Quebec H1E 1Z9, Canada
Citizenship: Canadian
Post Office Address: 12750, 27TH Avenue, Montreal, Quebec H1E 1Z9, Canada

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

All attorneys listed under Customer No.: 2512

Send Correspondence to:

Customer No.: 2512

Direct Telephone Calls to: (name and telephone number)
Clarence A. Green, Reg. No.: 24,622 (203) 259-1800

1-00

Full name of sole or first inventor:
Christer SINDERBY

Sole or first inventor's signature: Christer Sinderby DATE March 25, 2002

Residence:
12750, 27th Avenue, Montreal, Quebec H1E 1Z9, Canada CAX

Citizenship:
~~Canadian~~ Swedish

Post Office Address:
12750, 27th Avenue, Montreal, Quebec H1E 1Z9, Canada

2-00

Full name of second inventor:
Jennifer BECK

Second inventor's signature: Jennifer Beck DATE 25/03/02

Residence address:
12750, 27TH Avenue, Montreal, Quebec H1E 1Z9, Canada CAX

Citizenship:
Canadian

Post Office Address:
12750, 27TH Avenue, Montreal, Quebec H1E 1Z9, Canada

Full name of third inventor:
Lars LINDSTROM

Third Inventor's signature:

DATE

Residence address:
Lekevallsgatan 46, S-431 69 Moindal, Sweden

Citizenship:
Swedish

Post Office Address:
Lekevallsgatan 46, S-431 69 Moindal, Sweden

Full name of fourth inventor:

Fourth inventor's signature:

DATE

Residence address:

Citizenship:

Post Office Address:

Full name of fifth inventor:

Fifth inventor's signature:

DATE

Residence address:

Citizenship:

Post Office Address:

☐ Check here if additional pages are attached. Number of added pages:

3-00

Full name of third inventor:
Lars LINDSTROM

Third inventor's signature: DATE
Lars Lindstrom, April 3rd, 2002

Residence address:
Lekevallsgatan 46, S-431 69 Moindal, Sweden SEX

Citizenship:
Swedish

Post Office Address:
Lekevallsgatan 46, S-431 69 Moindal, Sweden

Full name of fourth inventor:

Fourth inventor's signature: DATE

Residence address:

Citizenship:

Post Office Address:

Full name of fifth inventor:

Fifth inventor's signature: DATE

Residence address:

Citizenship:

Post Office Address:

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